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SOME RECENT DEVELOPMENTS IN BALLISTIC-RANGE EQUIPMENT AND TESTING TECHNIQUES

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ABSTRACT: 33701

This paper describes several innovations in testing technique and equipment in use in the ballistic-range facilities at the Ames Research Center of NASA. In addition, a listing, with pertinent dimensions of the test facilities and launching guns, is included. AUTHOR: Author

BALLISTIC-TEST FACILITIES

Table I lists the ballistic-test facilities in current operation at Ames Research Center. Pertinent physical dimensions and special characteristics are noted.

MODEL-LAUNCHING GUNS

Table II lists the model-launching guns in active operation at Ames Research Center. Physical dimensions and operational characteristics are noted.

RADIATION DETECTION AND MEASUREMENT

Long-Duration Spectrographic Studies of Ballistic Models

In order to increase the time during which radiant energy from a model in free flight falls on the entrance slit of a spectrograph, the arrangement shown in figure 1 was used. A 1-1/2-inch-diameter hole was trepanned through the center of a spherical mirror of 6 inch diameter and 32 inch focal length.

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The model trajectory passes through the hole. The image of the model is focused at the spectrograph entrance slit for an appreciably longer time than was possible by viewing the model from the side. In answer to the obvious question, there have been five successful rounds out of six attempted.

Two rapid-acting shutters are used - one placed just ahead of the slit and closed just before the model comes into the vicinity of the mirrors; the second is placed at the entrance to the test chamber and closed after the passage of the model to prevent the radiant gases from the gun coming into the field of view of the spectrograph and saturating the photographic record. These shutters are simple and have an operating time of about 90 microseconds. A sketch of these shutters is shown in figure 2. An explosive squib, EBW PR-500, is placed in the insert in the base block, as shown. Upon actuation of the squib, the gases twist the cantilevered plate out of the way, sealing off the opening. The squib is not contained. Indeed, use of a hole smaller than 1 inch diameter tends to destroy the base block. The squibs were fired by the discharge of a 1/2-microfarad condenser charged to 3 kilovolts.

Light-Amplification Tests on Abtronics Image Converters

Some simple tests were made on the Abtronics 1-inch- and 2-1/2-inch-diameter image converters in an attempt to determine their effective light amplification. The units themselves will amplify the incident light; however, not all of this amplified light is useable since the amplified image, formed at the photo-anode surface, acts as a true source and radiates in all directions. Because of insulation requirements and the use of finite thickness glass, it is not possible to place film directly on the photo-anode. A camera must be used to photograph the image. The fact that cameras have limited light-gathering power and can capture only a small percentage of the total light output at the photo-anode reduces the total effective light amplification of the image converter.

Figure 3 shows the test arrangement. Filtered light from a spark unit, between 4100 and 4300 Å, was allowed to fall on the four units shown: (1) a 1P28 photomultiplier tube, connected in turn to an oscilloscope; (2) an open Polaroid Land camera back; (3) a 1-inch-diameter Abtronics image converter; and (4) a 2-1/2-inch-diameter Abtronics image converter. The lenses on the front of the image converters were removed to allow the light to fall directly on the surface of the image converter. Polaroid ASA 3000 film was used in the open camera back and in the cameras of the image converters, both of which used f/1.9 lenses. The 1-inch unit is supplied with a supplementary set of lenses between the photo-anode surface and the conventional camera lens. Photographic step-wedges were placed in the field of view of each of the three film arrangements.

It was determined that about 40 percent of the total light incident from the spark unit was shuttered through the image converters, considering both the time at which the shuttering was initiated and the duration of the shuttering pulse.

Comparison of the photographic step-wedge images on the three films and consideration of the shuttering action of the image converters allowed an evaluation of the light-amplification characteristics of the image converters with respect to the incident light. These results are as follows: the 1-inch-diameter image converter - camera unit produced an image that was 1/4 the intensity of the original. The 2-1/2-inch-diameter image converter - camera unit produced an image that was 1/40 that of the original.

Some Techniques of Calibration of Multiplier Phototubes

In the use of multiplier phototubes as radiometers of high-intensity events of very short duration (microseconds),[1] two calibration problems often arise: the determination of the absolute calibration and the determination of the linear operating range (saturation) of the detector. Relatively simple techniques which have been found useful in these cases are described.

Absolute calibration.- To preserve short rise-time characteristics of a detector operating several meters from the recording system (without resorting to the added complexities of cathode followers), the output resistor of the multiplier phototube divider circuit must be small, generally a few hundred ohms, to obtain the desired RC product. With a small output resistor, sensitivity is low and the detector's response to the calibration source (e.g., a tungsten lamp) may be below the noise level of the recording system at the necessary dynode high voltage. In such a case energy from a standard lamp, chopped at low frequency, is projected on the detector. The output voltage, measured across the small output resistor, R_o, is often too low to be read accurately on conventional oscilloscopes; that is, less than 0.1 mv. A simple modification of the divider circuit (Fig. 4) is to introduce a variable resistance, R_s, which raises the output voltage to readable levels without lowering the frequency response of the detector below that of the chopping frequency. Ohm's law is then used to calculate performance with the desired load resistor, assuming the tube to be a constant current source. Figure 5 shows typical data plotted on logarithmic scale for various dynode high

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[1]For example, see: Craig, Roger A., and Davy, William C.: Thermal Radiation From Ablation Products Injected Into a Hypersonic Shock Layer. NASA TN D-1978, 1963.

voltages. The slope is unity, because of the linearity of Ohm's law, and, when the output resistance is zero, the output voltage vanishes. Included for comparison are data for calibration voltages high enough to provide recordable output voltages.

Saturation calibration.- The operation of a detector in a linear response range requires knowledge of the saturation characteristics of the detector. Unfortunately saturation characteristics of multiplier phototube systems depend upon pulse duration when capacitors are used in the divider circuit to maintain dynode voltages during short (microsecond) pulse operation. Thus for short-duration events the standard methods for determining saturation[2] cannot be used. To simulate the test event in rise time and duration, a highly repeatable, high-intensity, short-duration light pulse from a General Radio Strobotac model 1531A was imaged through a lens on the photocathode. An iris in the lens varied the intensity. This system was then used to measure the apparent transmission of a neutral-pass optical filter of 10 to 20 percent transmission. The apparent transmission is given by

$$\text{Apparent transmission} = \frac{\text{output voltage with filter in light path}}{\text{output voltage without filter in light path}} = \frac{V_{in}}{V_{out}}$$

When the light intensity was raised to the extent that the detector is saturated, V_{out} was no longer a linear function of the incident radiation. Since the transmission of the filter is from 0.1 to 0.2, it was possible to cause V_{in}/V_{out} to change measurably by saturation. Saturation was noted as an abrupt change in the apparent transmission. The range of values of V_{out} for

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[2]Lallemand, A.: Photomultipliers. Sec. 6, Astronomical Techniques. W. A. Hiltner, ed., Univ. of Chicago Press, 1962.

which V_{in}/V_{out} remains correct is the linear operating range.

Stability and Control

Plastic-coated models.- Maintaining the integrity of gun-launched models throughout the trajectory is important for stability tests. Sharp metal models, in particular, tend to burn at high speeds and air densities. Tests at speeds of at least 18,000 ft/sec on 1/2-inch-diameter ballasted metal cones of 60 degrees total angle have been made possible by coating the models with plastic. Untreated models of this configuration were limited to velocities of less than 15,000 ft/sec.

A polymer, vinylidene fluoride, $CH_2 = CF_2$, dispersed in a carrier, was sprayed on the grit-blasted model surface to a thickness of about 0.015 inch in four laminates, with curing, 600° F for 25 minutes, between each coat. The models were remachined and trimmed to give a final coat thickness of about 0.007 inch. The trade name for the plastic used was KYMAR, produced by Pennsalt Chemicals. A local plastic shop performed the spraying and curing at a cost of $9 per model in lots of less than 10.

Verification of the effectiveness of the coating was obtained in an interesting way. One of the models, made of an aluminum base and a tungsten nose, failed at the joint during a high-speed launch. The aluminum, pushed out at the failed joint, burned vigorously while the sharp tip of the cone, still protected by the plastic, was maintained. Figure 6 is a focused shadowgraph of that model. This particular shadowgraph used a Kerr cell to act as a shutter at the crossover point of the collecting mirror. The film from the shadowgraph stations without the Kerr cells were all fogged. As a sidelight, it was determined that the aluminum bases of the models were weakened during the curing cycle for the plastic. The model bases are now being made from titanium.

TABLE I.- BALLISTIC TEST FACILITIES

AMES RESEARCH CENTER, NASA

Name	Counterflow	Number of shadowgraph stations	Diameter, m	Length, m	Comments
Supersonic Free-Flight Wind Tunnel	M = 2 M = 3	9	0.6	7.3	Stability tests.
Pilot Hypervelocity Free-Flight Facility	M = 5	2	.2	1.1	Radiation measurements. Cold helium shock-tube drive for counterflow, V_∞ = 1850 m/sec.
Prototype Hypervelocity Free-Flight Facility	M = 7	11	.6	12.2	Stability and radiation tests Spectrograph. V_∞ = 1850 to 4600 m/s. Cold helium and combustion shock-tube drive for counterflow.
Pressurized Ballistic Range	no	24	3.3	76	Stability tests. Speeds limited by visible radiation from the model.
Range No. 1	no	16	2.4	158	Microwave wake studies, momentum transfer, impact.
Pilot Range	no	7	.3	13.7	Passive telemetry, radiation, impact.
Janus Range	no	4	.3	4.6	Impact, B&W Model 189 camera.
Impact Range	no	6	.4	2.4	Impact. X-ray units.

All stations equipped for orthogonal shadowgraphs of models.

TABLE II.- HIGH-SPEED MODEL LAUNCHERS

AMES RESEARCH CENTER, NASA

Launch tube bore size, cm	Type **	Launch tube, L/D	Pump tube dia/L/D, cm	Piston weight, gm	Charging gas/pressure, psia	Powder charge, gm	Model weight, gm	Velocity, km/sec
1.27	D.P.	288	5.4/198	800	H_2/40	180	1-5	8.5-6.5
.71	S.C. 2-stage	318	3.8/24 2.0/69	7.5	He/400 H_2/400	110	.15	8.0
.76	S.C.	100	2.0/15	10	He			3.0
.56	D.P.	700	3.2/46	220	H_2/40	75	.1-.2	8.5-7.8
.56	D.P.	190	2.0/250	70	H_2/60	190	.1	8.5
.56	D.P.	220	4.5/137	690	H_2/42	80	.1	8.5
1.52	D.P.	200	4.5/137	340	H_2/85	180	3.0	5.5
2.00	S.C. 2-stage	220	10.2/24 5.7/61	135	He/300 H_2/240	850	4	8.0

** D.P. - Deformable piston
S.C. - Shock compression

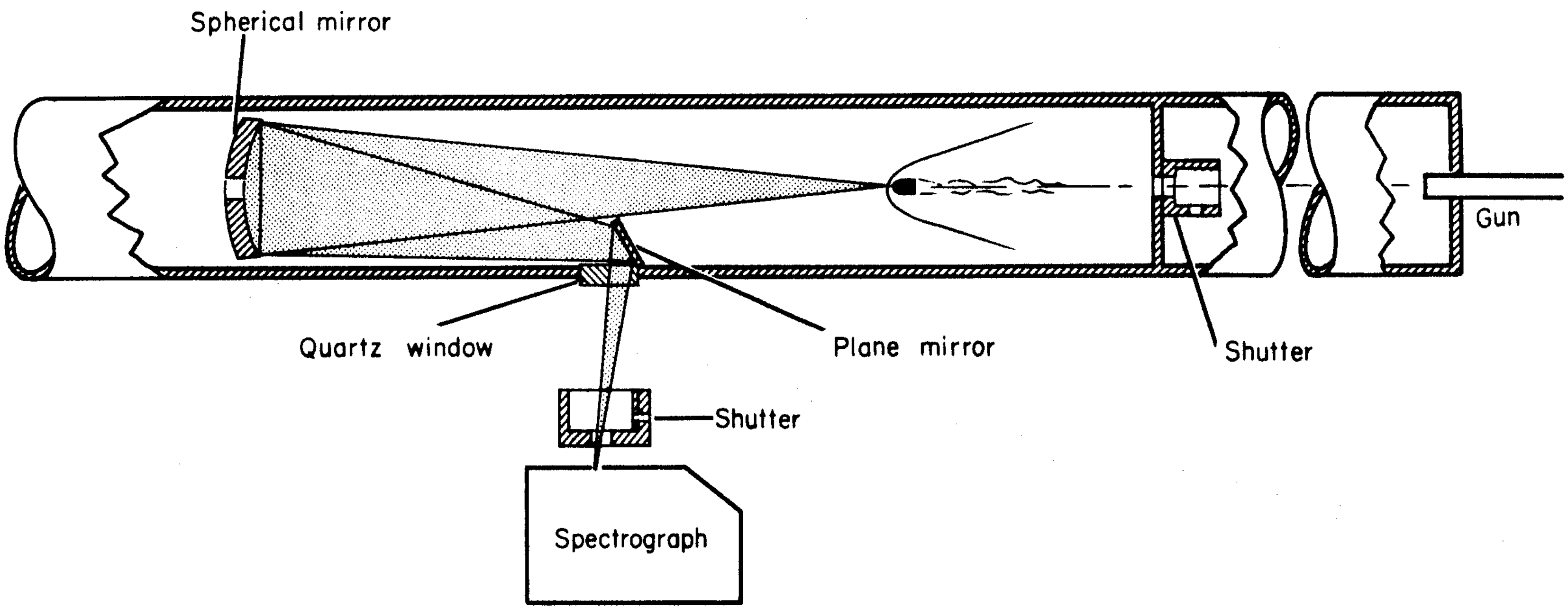

Fig. 1. Long duration spectrographic study test equipment.

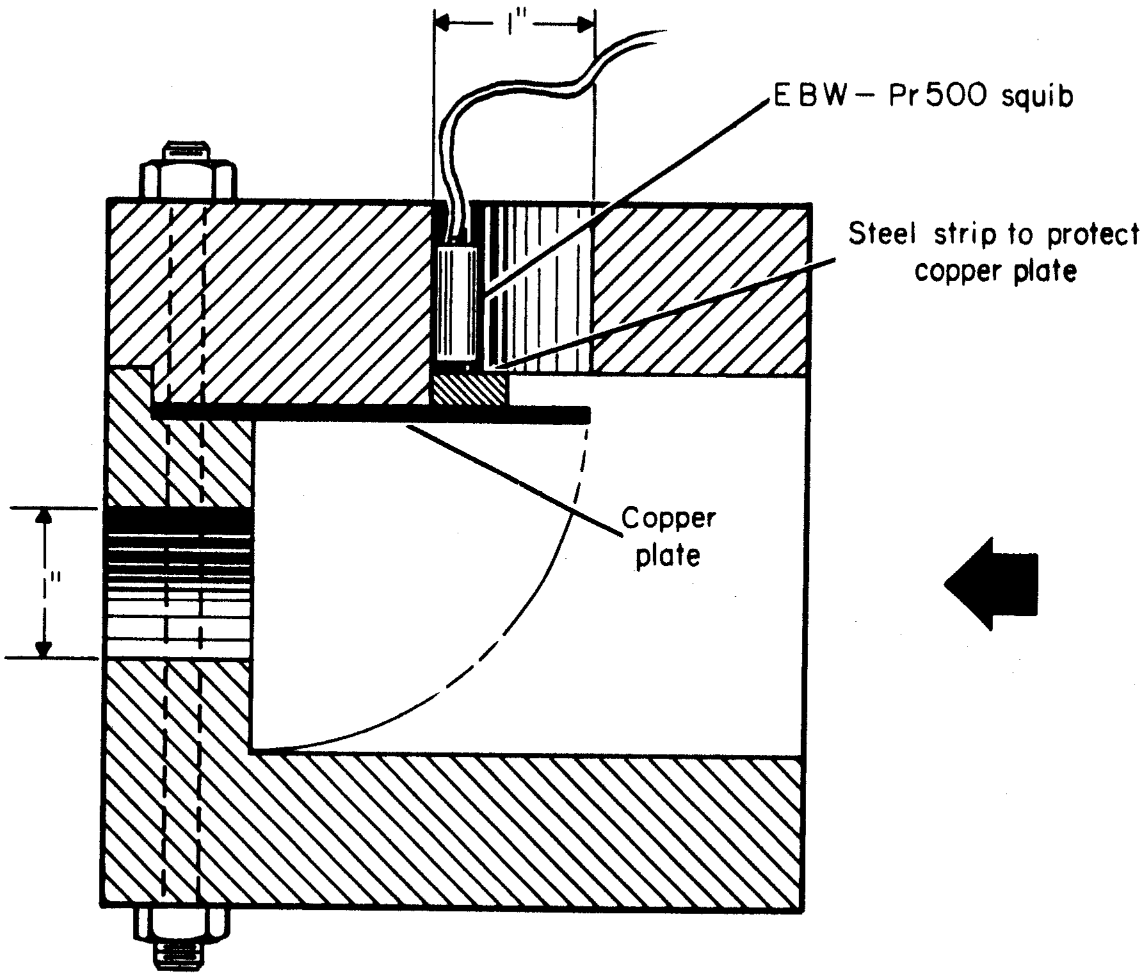

Fig. 2. Section view of explosive shutter.

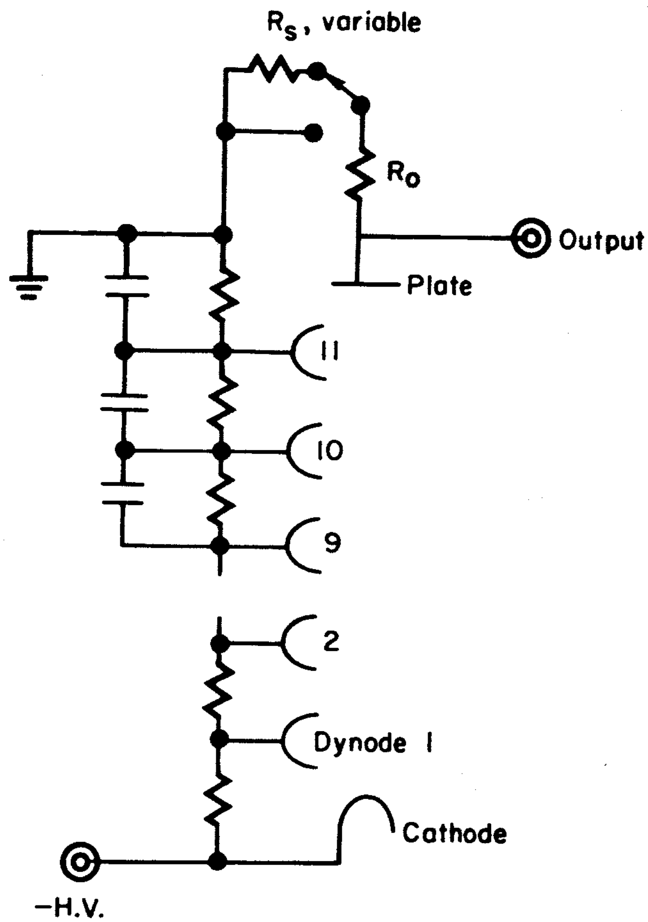

Fig. 4. Multiplier phototube divider circuit.

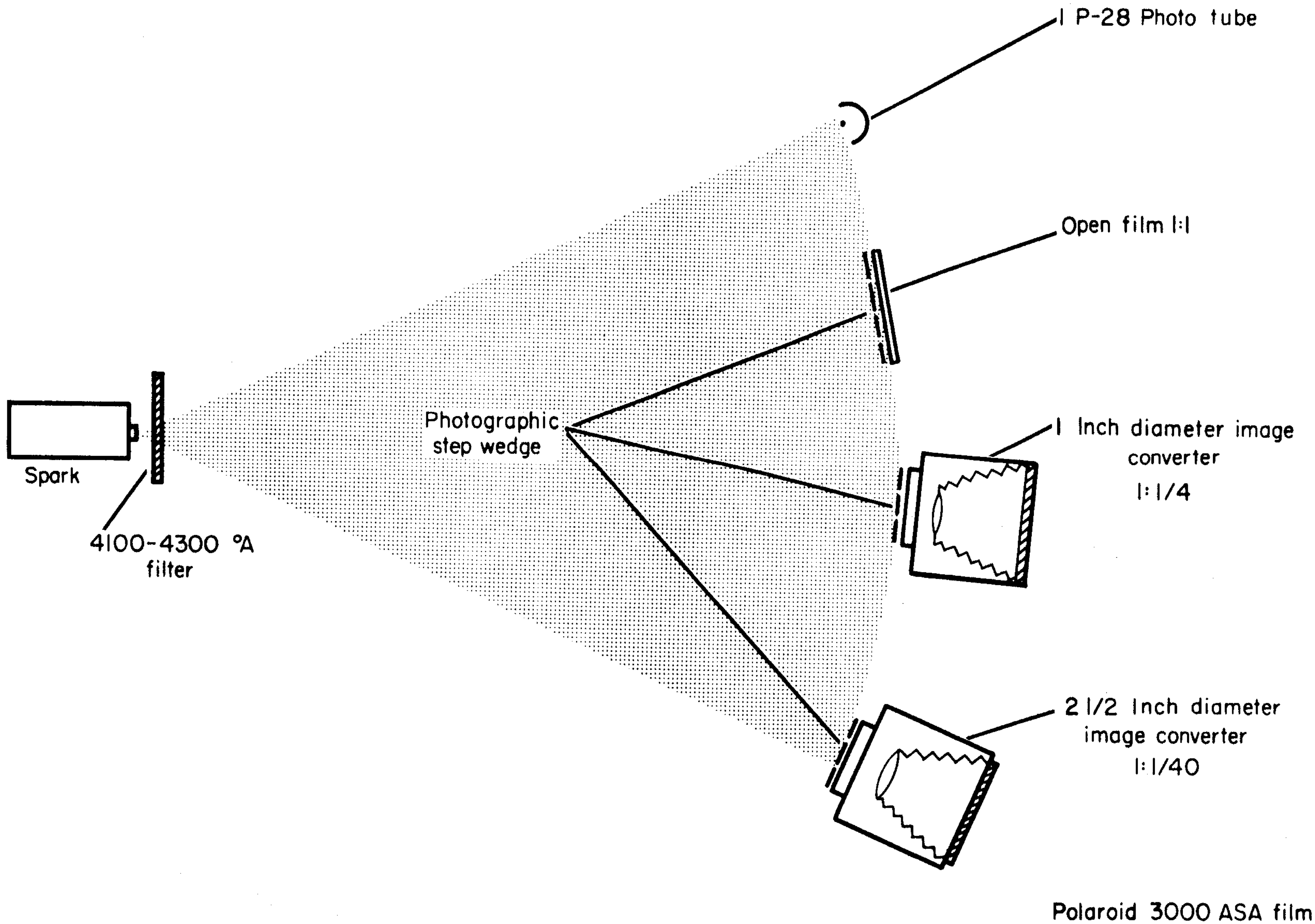

Fig. 3. Light amplification test arrangement.

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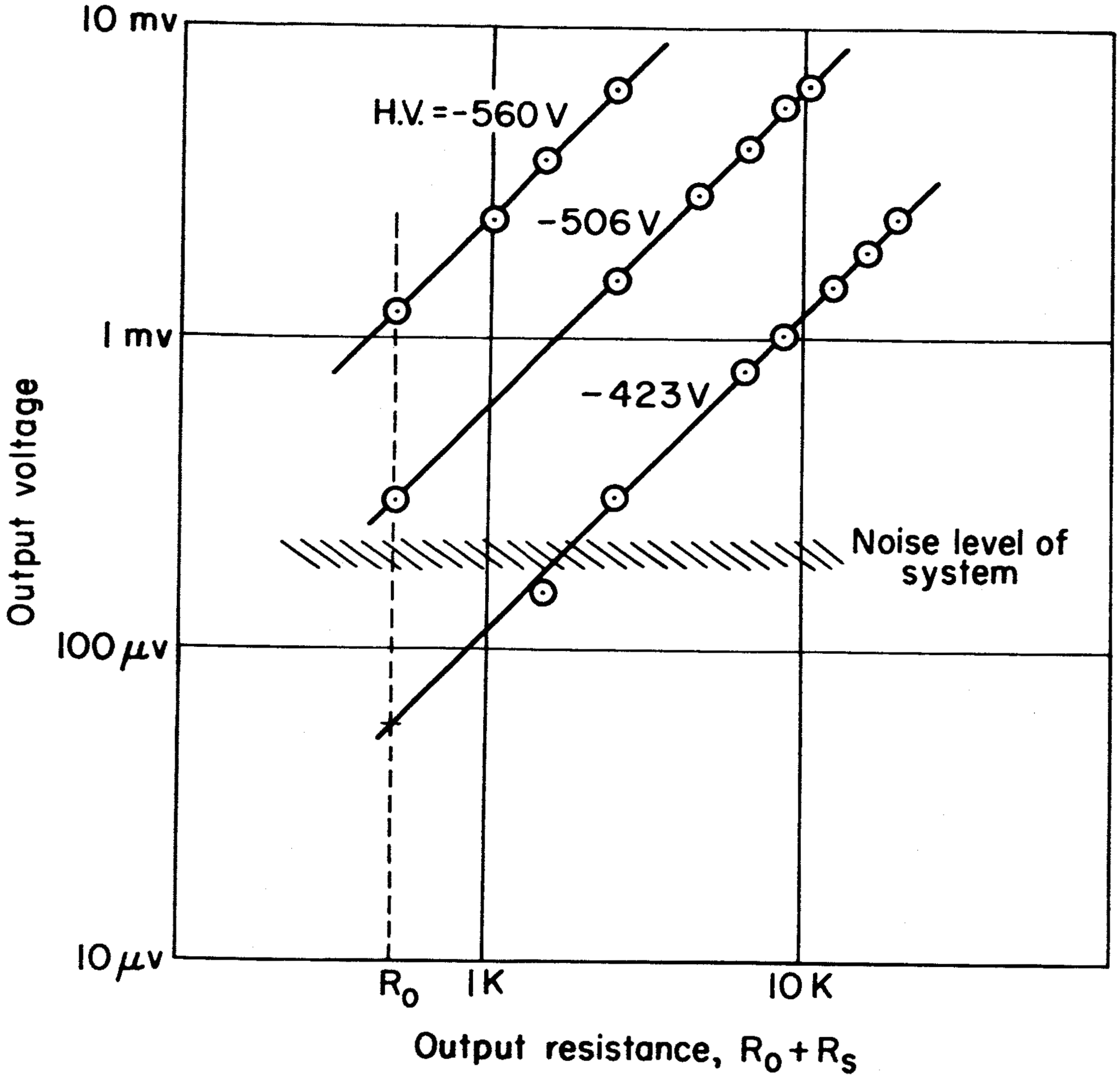

Fig. 5. Variation of output voltage with output resistance, allowing extrapolation to values below noise of system.

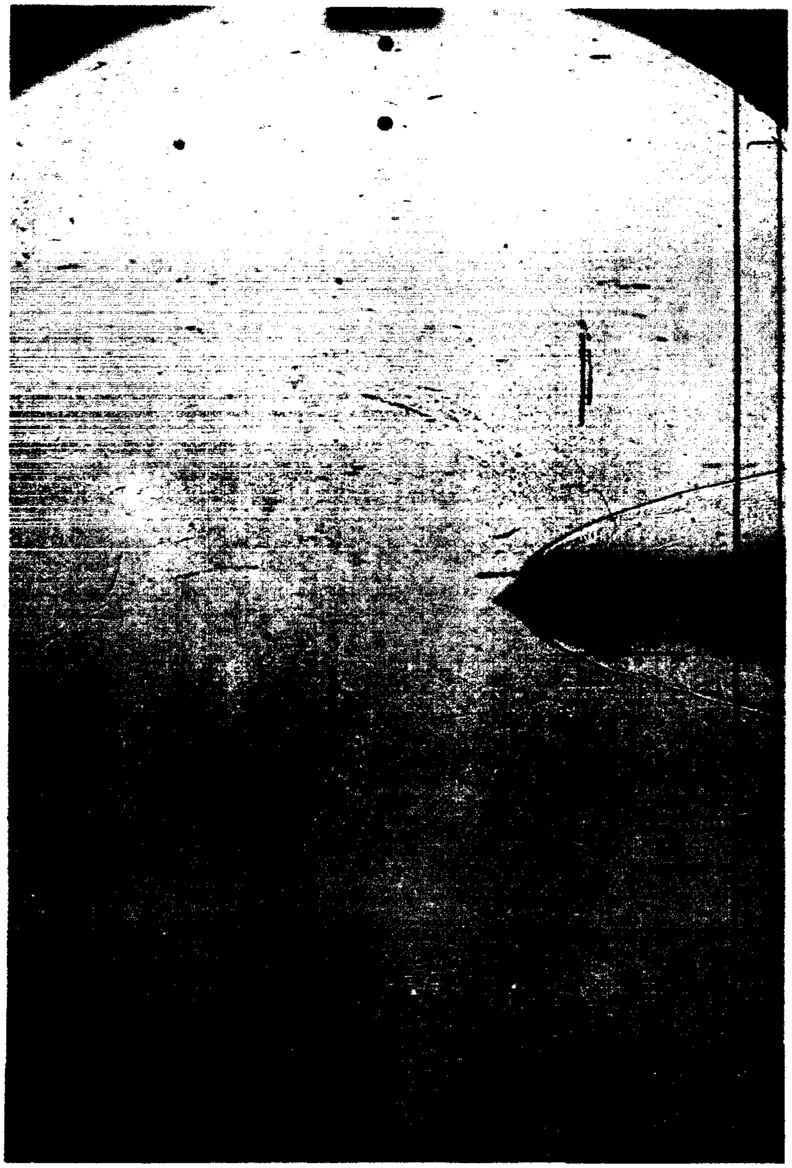

Figure 6.- Kerr Coll - shuttered shadowgraph of Damaged Model.